



Investigation of Anomalous Heat Observed in Bulk Palladium

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BACKGROUND: “Cold Fusion”?



Headlines 1989

Two electrochemists...

Martin Fleischmann

Stanley Pons

claimed to have tapped nuclear power
in a simple electrochemical cell.

*"It could be the end of the fossil fuel
age: the end of oil and coal. And the
end, incidentally, of many of our
worries about global warming."*

-- Sir Arthur C. Clarke

BACKGROUND: The Advantage of Fusion

Burning Coal:

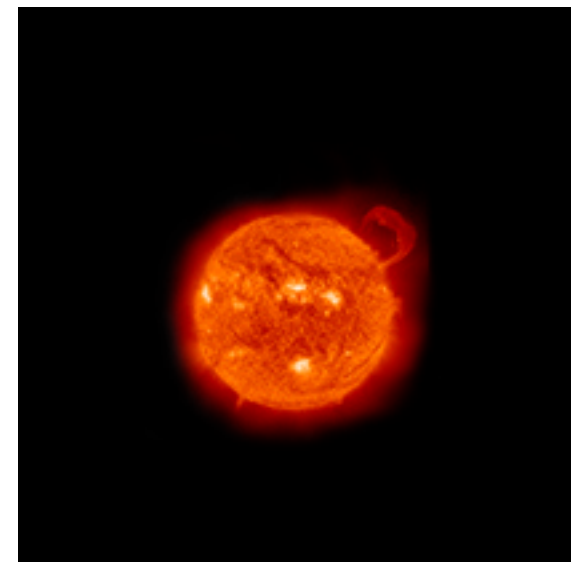
- $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ (4 eV)

Fission Power Reaction:

- $^{235}\text{U} + \text{n} \rightarrow ^{236}\text{U}$
 $\rightarrow ^{141}\text{Ba} + ^{92}\text{Kr} + 3\cdot\text{n}$ (170 MeV)

Fusion Processes:

- $\text{D} + \text{D} \rightarrow \text{T}$ (1.01 MeV) + p (3.02 MeV)
- $\text{D} + \text{D} \rightarrow ^3\text{He}$ (0.82 MeV) + n (2.45 MeV)
- $\text{D} + \text{D} \rightarrow ^4\text{He}$ (73.7 keV) + γ (23.8 MeV)
- $\text{D} + \text{T} \rightarrow ^4\text{He}$ (3.5 MeV) + n (14.1 MeV)
- $\text{D} + ^3\text{He} \rightarrow ^4\text{He}$ (3.6 MeV) + p (14.7 MeV)
 - $\text{D} = ^2\text{H}$, $\text{T} = ^3\text{H}$
- Fusion is at least 13% more productive per mass of fuel (without the nasty waste products)



BACKGROUND: 1989 Cold Fusion Experiment

- Tested non-electrochemical variant of “Cold Fusion” – where Deuterium (D_2) gas used with palladium (Pd) filter
- Used Pd filter from hydrogen purifier
- Gas is “loaded” and then “unloaded” from palladium, while monitoring purifier temperature and neutrons.
- Compared to Hydrogen gas as the experimental control.



Results

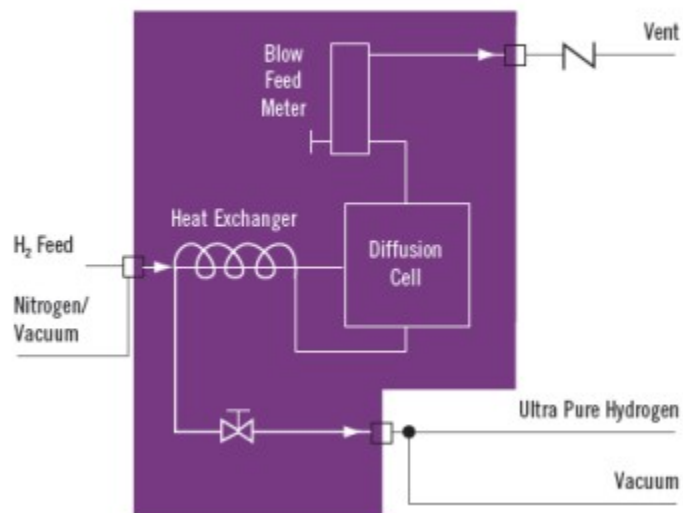
- Published: *Fralick, Decker, & Blue (1989) NASA TM-102430*
- 15°C increase in purifier temperature consistently seen with D_2 that was not seen with the H_2 control when gasses were unloaded from the purifier.
- Neutron detector counts did not differ significantly ($\leq 2\sigma$) from background in any run (Monitored with BF_3 w/ Polyethylene [“Snoopy”] detectors).

BACKGROUND: Purifier Schematic

- Johnson Matthey HP Series palladium membrane hydrogen purifier
- Used in the semiconductor industry and applications where ultra-high purity hydrogen is required (to 99.9999999%)
- An at-hand substitute for a palladium electrolytic cell



Flow Diagram HP Series



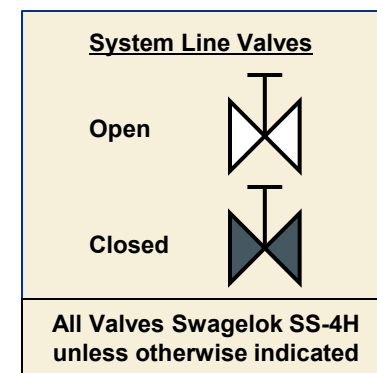
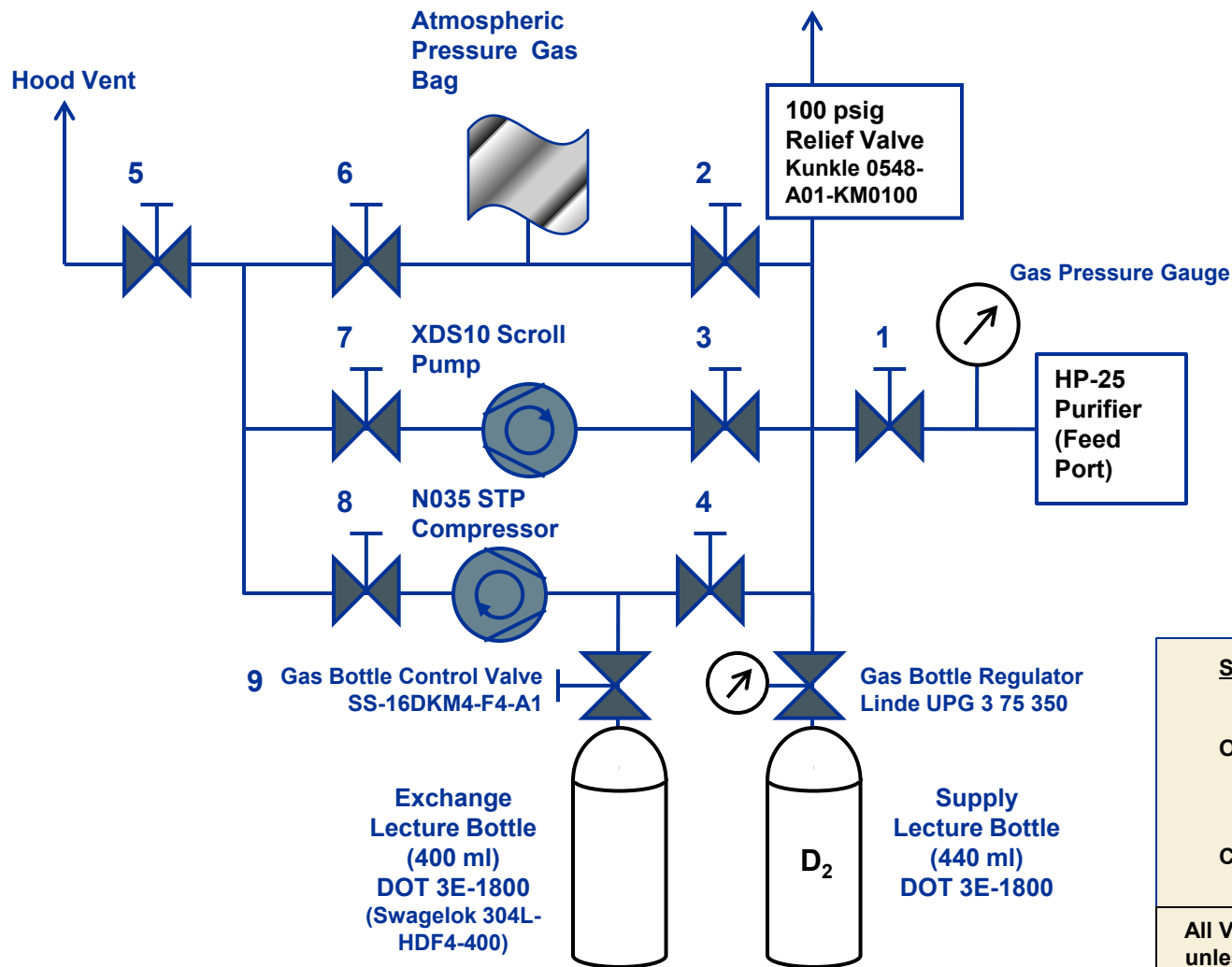


BACKGROUND: Changes from 1989 to 2009

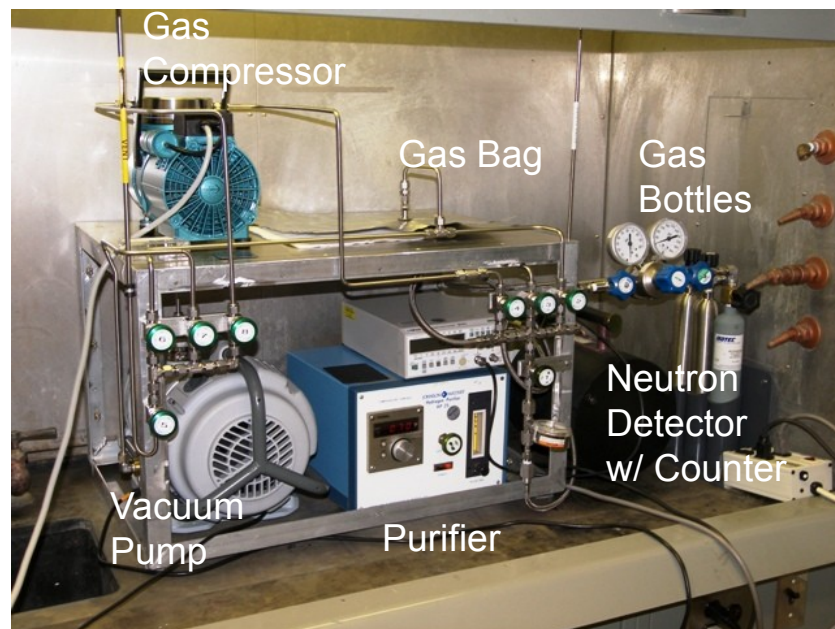
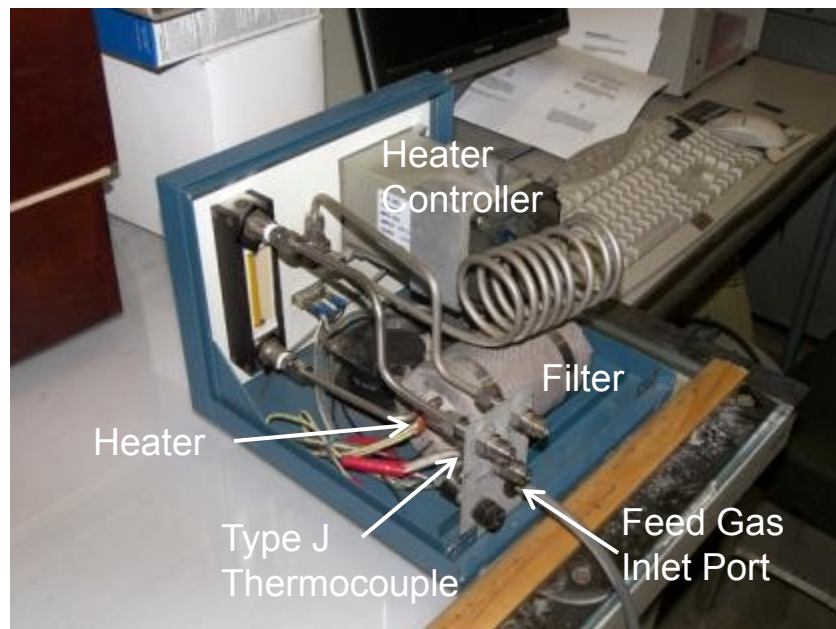
- Previous NASA experiment (Fralick, et al.; 1989) looked for neutrons (saw none) – but saw anomalous heating
- After 1989, Cold Fusion research evolved into research in “Low Energy Nuclear Reactions” (LENR), primarily at U.S. Navy, DARPA & various Universities
- Some recent LENR theories suggest He-3,-4 generation or transmutations occurring in PdH/D is the cause of anomalous heating
- **2009: NASA IPP-sponsored effort to:**
 - Repeat the initial tests to investigate this anomalous heat
 - Apply GRC’s instrumentation expertise to improve the diagnostics for this experiment
 - Establish credible framework for future work in LENR



APPROACH: Flow System Schematic



APPROACH: 2009 Test Apparatus



- Johnson Matthey HP-25 hydrogen purifier
 - Purifier Filter contains a ~50g heated Pd-25%Ag membrane
- Load Filter by flowing hydrogen gas into the purifier
- Unload Filter by pumping the gas out of the purifier into a sample bottle
- Turn off filter heater for a time when Loading & Unloading
- Monitor changes in temperature, neutron/gamma background
- Repeat with deuterium gas; Compare results



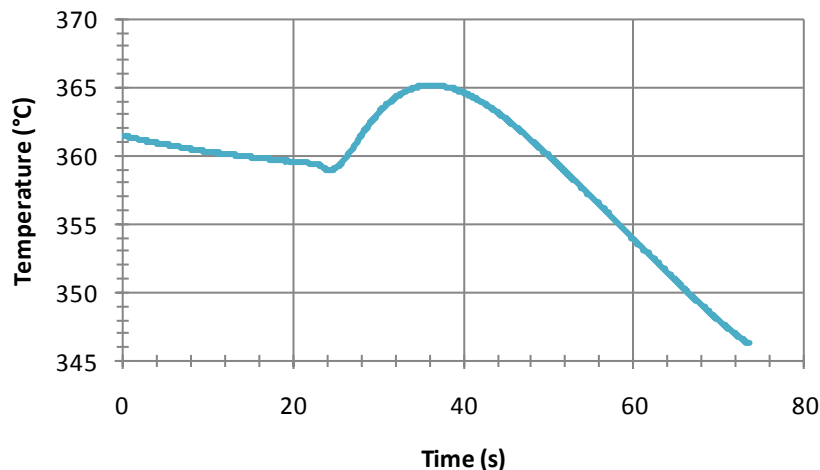
RESULTS (Preliminary): Temperatures vs. Time

Loading

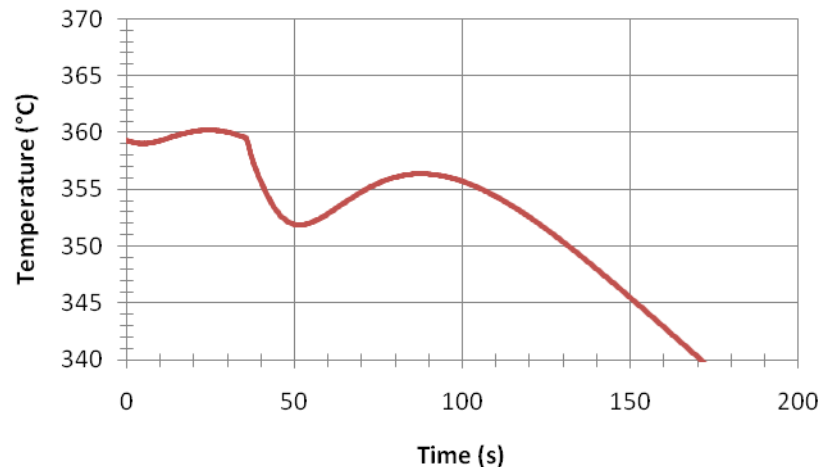
Unloading

Hydrogen

Observed Temperature for H2 Load

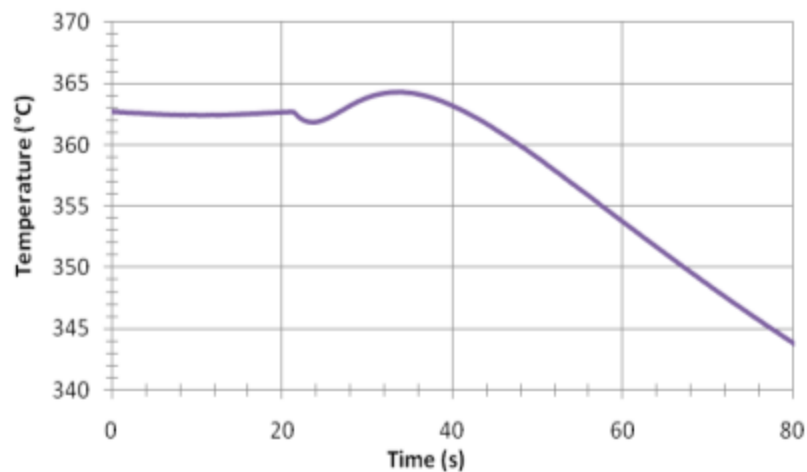


Observed Temperature for H2 Unload

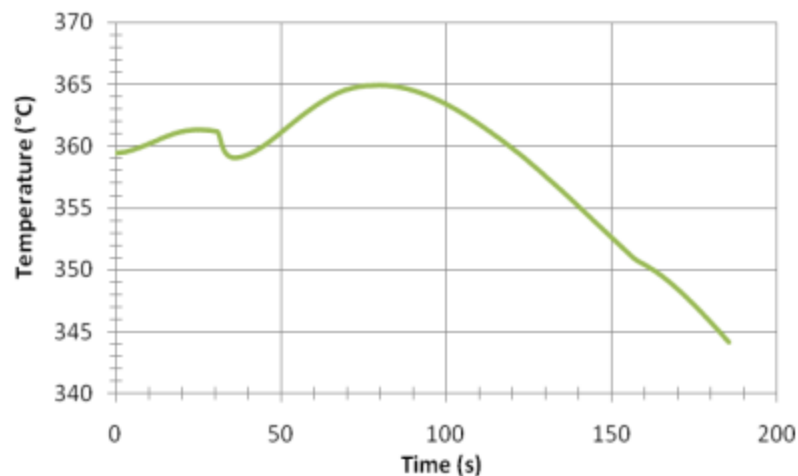


Deuterium

Observed Temperature for D2 Load



Observed Temperature for D2 Unload





The Path Forward

- More loading/unloading data on the temperature evolution of the loading/unloading process should be collected
- Analysis of the gas samples collected should be performed to look for evidence of tritium or helium
 - Mass spectrum analysis and optical emission spectrum analysis should be able to identify gas species in the samples
 - Existence of either in the sample would indicate a nuclear origin for the anomalous heating
- Further examination of the thermodynamics of hydrogen absorption in palladium should be pursued to fully quantify the extent of the observed heating effects
- Improve experiment controls:
 - Upgrade Purifier heater control
 - Improve loading/unloading process timing
 - Fabricate in-house palladium samples
 - Improve neutron and gamma radiation detection



References

- Fralick, Gustave C.; Decker, Arthur J. and Blue, James W.: “Results of an Attempt to Measure Increased Rates of the Reaction $^2\text{D} + ^2\text{D} \rightarrow ^3\text{He} + \text{n}$ in a Nonelectrochemical Cold Fusion Experiment,” NASA TM-102430 (1989).
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